Regional Environmental Monitoring and Assessment Program - Galveston Bay 1993

Cynthia Gorham-Test
Aquatic Scientist
Texas Natural Resource Conservation Comm.

*The Galveston Bay REMAP Report was prepared while Ms. Gorham-Test was employed as an Environmental Scientist in the Watershed Management Section of the U.S. Environmental Protection Agency, Region 6 Office.

Employer: Texas Natural Resource Conservation Commission, from July 1998 to present.
Position: Aquatic Scientitst/Hydrologist in the Water Quantity Division
Major focus: Freshwater Inflow Needs for Texas Bays and Estuaries, and Instream Flow Needs.

Employer: U.S. Environmental Protection Agency, Region 6, from February 1997 to June 1998
Position: Environmental Scientist in the Watershed Management Section
Major Accomplishments:
1) Analyzed data and prepared two reports on the REMAP data collected from the estuarine systems of Galveston Bay, East Bay Bayou, Arroyo Colorado, and the Rio Grande.
2) Prepared an inventory and a nitrogen and phosphorus loading analysis of Point Source Dischargers to the Mississippi River Watershed and Louisiana's Coastal Watersheds.

Employer: Lower Colorado River Authority, from July 1992 to September 1996.
Position: Coastal Ecologist in the Environmental Division
Major accomplishments:
1) Determined a nutrient budget for the Lavaca-Colorado Estuary, and determined recommended freshwater inflow needs to meet minimum nitrogen needs.
2) Established and implemented a water quality monitroing program for Matagorda Bay.
3) Established and maintained the Matagorda Bay Area volunteer water quality monitoring program.

Education: University of Texas from August 1990 to June 1992
Position: Ph.D. student/teaching assistant for Ecology, Limnology, and Introductory Biology.

Education: Baylor University from August 1988 to August 1990
Position: Graduate student/teaching assistant for Introductory Biology and Animal Physiology,

Education: Baylor University from August 1986 to August 1988
Position: Undergraduate student/teaching assistant for Introductory Biology and Limnology Research Assistant for Dr. Owen Lind.

Degrees Received:
Master of Science degree in August 1988.
Bachelor of Science degree in August 1990.
Associate of Arts degree from McLennan Community College in May 1985.

Cynthia Gorham-Test

Publications:

"The effects of low pH environments on the predation rate, respiration rate, and caloric content of damselfly nymphs (*Enallagma civile*)." Hydrobiologia, 1991.

"A Study Guide to accompany an Introductory Biology Lab Manual by Vodopich and Moore." Stipes Publishing, 1994, 1997.

Published Reports:

"The LCRA's Bays and Estuaries Program." Clean Rivers Act Report, 1994.

"The Lavaca-Colorado Estuary." Clean Rivers Act Report, 1996.

"A Nutrient Budget and Requirements for the Matagorda Bay System." In: "Freshwater Inflow Needs of the Matagorda Bay System", LCRA Report, 1997.

"Regional Environmental Monitoring and Assessment Program - Gaiveston Bay 1993." In Progress for publication.

"Regional Environmental Monitoring and Assessment Program - Texas Estuaries 1993." In Progress for publication.

Offices Held:

Chairperson/Vice-Chairperson for the Freshwater and Marine Section of the Texas Academy of Science 1997-98/1996-97.

Treasurer for the Texas Rivers and Reservoirs Management Society (Texas Chapter of NALMS) 1996-1998, 1998-2000 (two terms).

REGIONAL ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM - GALVESTON BAY 1993

Cynthia Gorham-Test, U. S. Environmental Protection Agency, Region 6, Dallas, Texas

Terry Wade, Texas A&M University, Geochemical and Environmental Research Group, College Station, Texas

Virginia Engle and Kevin Summers, U. S. Environmental Protection Agency, National Health and Environmental Effects Research Lab, Gulf Breeze, Florida

Evan Hornig, U. S. Environmental Protection Agency, Region 6, Dallas, Texas

The Regional Environmental Monitoring and Assessment Program (R-EMAP) Study of Galveston Bay, Texas was developed to address the ecological health of this estuary by identifying benthic community structure, measuring toxicity of sediments, and measuring concentrations of various pollutants in the sediments. The R-EMAP Study of Galveston Bay was proposed after the EPA's 1991 EMAP Study of the Louisianian Province estuaries identified Galveston Bay as an area of concern. The sampling design and ecological indicators employed for the R-EMAP Study of Galveston Bay are based on the EMAP concept, but they were limited to one sampling event and a locally intensified EMAP sampling grid was used.

The purpose of this study was to characterize the condition of Galveston Bay as a whole, characterize conditions of four small bays in the Galveston Bay Complex, and determine the impacts of marinas. For comparison of the main body of Galveston Bay with other systems and the Louisianian Province as a whole, twenty-nine randomly selected sites were chosen to represent 1305 km^2 of surface area of Galveston Bay. Random sites were located in Galveston Bay (GB), Trinity Bay (TB), East Bay (EGB), and West Bay (WGB). In addition, a random sample was taken for each of four important small bays associated with Galveston Bay: Clear Lake (CL), Dickinson Bay (DKL), Moses Lake/Dollar Bay (MLDL), and Offatt's Bayou (OB). Also, five marina sites (MA) were chosen to determine local marina influences (Map 1). This study did <u>not</u> include an analysis of conditions in the upper Houston Ship Channel, the Trinity River, or any other major tributaries.

The Louisianian Province EMAP Study consisted of 96 sites which represented 25,725 square kilometers of estuarine area. The Louisianian Province extends along the Gulf Coast from Anclote Anchorage, Florida to the Rio Grande, Texas.

A comparison of the EMAP Study of the Louisianian Province with the R-EMAP Study of Galveston Bay did provide insight into the differences between Galveston Bay and its Small Bay & Marina Sites, and the entire Louisianian Province. These comparisons revealed that the EMAP results were useful as a screening tool to determine which systems had toxic pollutants or biological impairment and therefore, should be studied in more detail.

The Sediment Quality Triad approach was used in this study to differentiate between degraded sites and undegraded sites. The Sediment Quality Triad consists of three components: Benthic Community Structure, Sediment Chemistry, and Sediment Toxicity. For this study, a degraded site was defined as a site which has at least two of the Sediment Quality Triad Components indicating degradation.

Benthic Community Component

Several metrics were used to determine the benthic community health. The most informative metrics were the benthic index (Engle & Summers, in press), the benthic diversity index (the Shannon-Weiner index), number of species per site and abundance of amphipods at each site. The Benthic Index incorporates both the diversity index and amphipod abundance (Engle, et. al., 1994). The Shannon-Wiener diversity index is a measure of both species richness and species evenness (i.e., the distribution of individuals among species). The proportions of the benthic index values in the Galveston Bay area were higher or similar to the proportions reported for the Louisianian Province in the 1993 EMAP Study (Table 1). In contrast, amphipod occurrence in Galveston Bay sediments was significantly lower than in the entire Louisianian Province sediments. Small Bay and Marina Sites in Galveston Bay had no amphipods present and had much lower index values relative to Galveston Bay and the Louisianian Province sites (Maps 2 & 3).

A degraded Benthic Component was found at 7 of 29 sites in Galveston, and 8 of 9 Small Bay & Marina Sites (Map 2).

Sediment Toxicity Component

Ampelisca abdita (the tube dwelling amphipod), and *Mysidopsis bahia* (a mysid shrimp) were used as the lab organisms to test toxicity. Toxicity was not seen when using mysid shrimp as a test organism, but toxicity was reported when using amphipods. Sites with toxic sediments included: Offatt's Bayou (OB), Dickinson Lake (DKL), and West Galveston Bay near Swan Lake (WGB1). Toxicity was present at 3.5% of Galveston Bay area and 22% of Small Bay and Marina sites. Toxicity could not be associated with any of the measured parameters including presence or absence of natural amphipod populations present at each site.

Toxicity results revealed a low occurrence of acute toxicity in Galveston Bay sediments.

Sediment Chemistry Component

Sediment contaminants analyzed included 44 individual Polynuclear Aromatic Hydrocarbons (PAHs), High Molecular Weight PAHs and Low Molecular Weight PAHs, 20 polychlorinated biphenyl congeners, 24 pesticides (including DDT and its derivatives), 15 heavy metals, and 3 forms of butyltin. Sediment grain size, percent silt-clay content, total organic carbon, and acid volatile sulfides also were measured.

The contaminants were compared to established criteria including NOEL, ERL, and ERM. The range-low (ERL) criteria was established using the lower 10^{th} percentile of effects data for the metal or chemical. Concentrations equal to or above the ERL, but below the ERM, were used to represent a possible-effects range within which effects would occasionally occur. The range-high (ERM) criteria was established using the 50^{th} percentile of the effects data. The concentrations equal to or higher than the ERM value were used to represent a probable-effects range within which effects would frequently occur (Long, et al., 1995). The concentrations equal to the NOEL value were used to represent the highest level at which "no observed effects' occurred (MacDonald, 1992). In addition, anthropogenic enrichment of metals was measured. Enrichment was determined using regression equations for each metal against aluminum concentrations in the sediments, because aluminum does not have a significant anthropogenic source. Aluminum values covaried with sediment texture and other heavy metals in the sediments. However, a significant relationship (R= -0.44) was not found between aluminum and the benthic index (Map 3).

In Galveston Bay, arsenic, copper, lead, nickel, and zinc exceeded the ERL but not the ERM criteria at one or more sites sampled (Table 2, Figure 1). NOEL values, but not ERL values, were exceeded at one or more sites for arsenic, chromium, lead, mercury, and zinc. Sites with the most metals contamination included Offatt's Bayou (OB), Clear Lake (CL), Moses Lake/Dollar Bay (MLDL), and two Marina sites (Map 4). All of these sites were Small Bay and Marina sites, which were chosen, not randomly selected, so they are not included in comparisons of Galveston Bay with the La. Province 1993 EMAP sampling area. However, several of the randomly sampled sites in Galveston Bay did have exceedences for arsenic, chromium, nickel, and zinc. Most sites with chromium, copper, lead, nickel, and zinc concentrations exceeding NOEL or ERL values were classified as having anthropogenic sources for these metals (Figure 2).

The Galveston Bay area (represented by the 29 randomly chosen sites) had chromium and nickel distributions that were higher than would be expected when compared to the entire Louisianian Province area. The percent of area with exceeded values in Galveston Bay were compared to the percent of area with exceeded values in the entire Louisianian Province as reported in Macauley, et al., 1995. Arsenic distributions in Galveston Bay were lower than expected when compared to the Louisianian Province, while zinc distributions were similar. Copper values above ERL values were found in the small bays and marinas. However, copper values above ERL valueswere not found in the randomly sampled area representing Galveston Bay, nor in the entire Louisianian Province area.

Tributyltin (TBT) is toxic to marine animals and is used in anti-fouling paint for boats, buoys, and docks. TBT has been restricted for use in recent years to only larger boats in an effort to reduce the amount of TBT contamination in the marine environment. Values exceeding 1.0 ppb in the sediments are used as a screening criterion based on studies by Laughlin, et al. (1984).

TBT concentrations were higher in Galveston Bay sediments than expected with values greater than 1 ppb occurring in 52% of the area, compared to 31% of the total Louisianian Province area (Figure 3). Considerably higher TBT values (13.3 ppb to 40.7 ppb) occurred at four of five marina sites and in Offatt's Bayou (Map 5). A significant relationship was found between butyltin concentrations in the sediments and butyltin concentrations in the water column.

Sites with high Dieldrin and Endrin concentrations in the sediments were located in upper Galveston Bay (GB1,2,3,4, MA2), Clear Lake (CL, MA3, MA4), and upper Trinity Bay (TB8, TB10).

For the Louisianian Province, Dieldrin and Endrin both were found to exceed the ERL guidelines at 57% and 18% respectively, of EMAP sites. Both Dieldrin and Endrin concentration exceedence by area were lower in Galveston Bay compared to the Louisianian Province. Dieldrin and Endrin ERL values were exceeded at 17% and 5% respectively in Galveston Bay, and 21% and 7% for Galveston Bay and the Small Bay and Marina sites. No other pesticides measured (including DDT and its associated metabolites) exceeded ERL values for either study.

Polynuclear Aromatic Hydrocarbons (PAHs) were examined for exceedence of NOEL, ERL, and ERM screening values. PAHs exceeding ERL values in Galveston Bay included only C3-fluorene at site TB5 in Trinity Bay where several active oil wells are located (Map 6). PAHs exceeding NOEL, but not ERL values in Galveston Bay included Acenaphthylene and High Molecular Weight PAHs only found at site TB5 in Trinity Bay. Distributions of Low Molecular Weight PAHs and High Molecular PAHs for Galveston Bay showed that three sites had PAHs that were considerably higher than at the other sites in the Galveston Bay area represented by the randomly chosen sites, TB5, WGB1, WGB2 (Map 6).

C3-fluorene exceeded ERL criteria in 3% of Galveston Bay (site TB5), which was similar to exceedences found in the entire area of the Louisianian Province. Also, the NOEL value for high Molecular Weight PAHs was exceeded at site TB5. In the Louisianian Province, only C3-fluorene ERL values and High Molecular Weight PAHs ERL values were exceeded.

Sites in East Bay Bayou, located on the Intracoastal Waterway (ICWW), also had PAH concentrations higher than ERL values. Sediment concentration in the ICWW exceeded ERL guidelines for C2- & C3- Fluorene and C3- Phenanthrene. Nearby oil fields could have been a possible continuous source of PAHs in this area (Map 6).

Polychlorinated Biphenyl (PCB) concentrations in Galveston Bay did not exceed the sediment quality low-level ecological effects screening value of 22.7 ppb. And, only 1% of the Louisianian Province area had exceedences of PCBs in the sediments.

The major variables used to determine degraded sediment chemistry in Galveston Bay included metals, butyltins, PAHs, pesticides other than DDTs, and silt-clay content. These variables were compressed into one factor using Principal Components Analysis (PCA). Sites with the highest compressed significant environmental factor values for sediment chemistry include Offatt's Bayou, Moses Lake/Dollar Bay, Clear Lake, four of the Marina sites, and two sites near large brine discharges in the Trinity Bay area (TB5 and GB6). These sites were located near the shorelines and near areas of high anthropogenic activities (Map 7).

Site Degradation

For this study, a degraded site was defined as a site with at least two of the Sediment Quality Triad Components indicating degradation. A marginal site was defined as a site with a benthic index value from 4.0 to 5.1 (which represents a marginal benthic component) and with a degraded sediment chemistry component. Heavy metal concentrations greatly influenced the determination of degraded sites for the Sediment Chemistry Component of the Triad.

The most degraded areas in the Galveston Bay Complex included seven Small Bay and Marina Sites and five randomly chosen sites in the open bay: Offatt's Bayou (OB), Clear Lake (CL) and its marina sites, Lafayette Landing and South Shore (MA3 and MA4), Upper Galveston Bay at the Houston Yacht Club (MA2), Upper Galveston Bay near the upper Houston Ship Channel (GB1), Upper Galveston Bay near Smith Point (GB7), Moses Lake/Dollar Bay (MLDL), Dickinson Lake (DKL),mid-Trinity Bay (TB5) and Trinity Bay near the river mouth (TB8, TB9), and mid-East Galveston Bay (EGB5) (Table 3, Map 8). Seventy-eight percent of the Small Bay and Marina Sites were degraded, compared to 48% of the open Galveston Bay area classified as either degraded or marginal. Most degradation was seen in areas nearer the shorelines, and in areas with high anthropogenic activities such as marinas, industrial activities, and oil wells.

ACKNOWLEDGMENTS

U.S. EPA Region 6, Water Quality Division: Jeff Catanzarita, Phil Crocker, Norm Dyer, Angel Kosfizer, James Stiebing, Kenneth Teague. U.S. EPA, ORD, Gulf Breeze Lab:Tom Heitmuller, John Macauley. U.S. EPA, ORD, EMAP: Rick Linthurst. Gulf Coast Research Group at USM IMS: Richard Heard, Tom Lytle, Ervin Otvos, Chet Rakocinski, William Walker. University of Mississippi: Carol Cleveland, Gary Gaston. Texas A&M University, Geochemical and Environmental Research Group: Bob Pressley. Texas Research and Analysis Corporation: Barbara Albrecht, Jerri Brecken-Folse. Texas Natural Resource Conservation Commission: George Guillen, Steve Twidwell.

Table 1. Benthic Community Structure Group Comparisons by Percent of Area or Sites.

	Benthic Index		
	<3	3 - 5	>5
GB Small Bays/Marinas	78%	11%	11%
Galveston Bay	17%	31%	52%
Louisiana Province	23%	37%	40%

Table 2. Metal Concentration Ranges, and NOEL & ERL Exceedences
in Sediments of Galveston Bay and Its Associated Small Bay & Marina Sites.

Heavy Metals	NOEL	ERL	Galveston Bay Percent Exceeded NOEL	ERL	Small Bays/Mari Percent Exceed NOEL	ERl	
Arsenic	8	8.2	17%	17%	33%	22%	33%
Chromium	33	51.0 (81.0)	72%	52% (0%)	89%	78% (0%)	9%
Copper	28	24.0 (34.0)	0%	0%	67%	67% (44%)	0%
Lead	21	46.7	38%	0%	67%	11%	0%
Mercury	0.1	0.15	0%	0%	11%	0%	3%
Nickel	NA	20.9	NA	55%	NA	78%	35%
Zinc	68	150.0	55%	4%	78%	22%	4%

ERL and ERM exceedence values were taken from Long, et al. (1995).
ERL and ERM exceedence values in parentheses were taken from Long and Morgan (1990).

Table 3. Degradation at Each Site Indicated by the Sediment Quality Triad Components.

Station	Benthic Index	Sediment Chemistry	Sediment Toxicity
GB1	X	X	
GB2	x	X	
GB3	X		
GB4	x	X	
GB5			
GB6	x	X	
GB7	X	X	
GB8			
GB9			
GB10	x	X	
GB11			
GB12			
TB1	x	X	
TB2	x	X	
TB3	x		
TB4			
TB5	X	X	
TB6			
TB7			
TB8	X	X	
TB9	X	X	
TB10	x		
EGB1			
EGB2		X	
EGB3	x	X	
EGB4		X	
EGB5	X	X	
WGB1			X
WGB2			
OB	X	X	X
MLDL	X	X	
DKL	X		X
CL	X	X	
MA1		X	
MA2	X	X	
MA3	X	X	
MA4	X	X	
MA5	X		

X = Values indicate degradation (Benthic Index Values less than 4.0),
x = Benthic Index Values between 4.0 and 5.1.

	ERL-As	ERL-Cu	ERL-Pb	ERL-Ni	ERL-Zn
Louisiania	33	0	0	35	4
Galveston	17	0	0	55	4
Small Bay	22	67	11	78	22

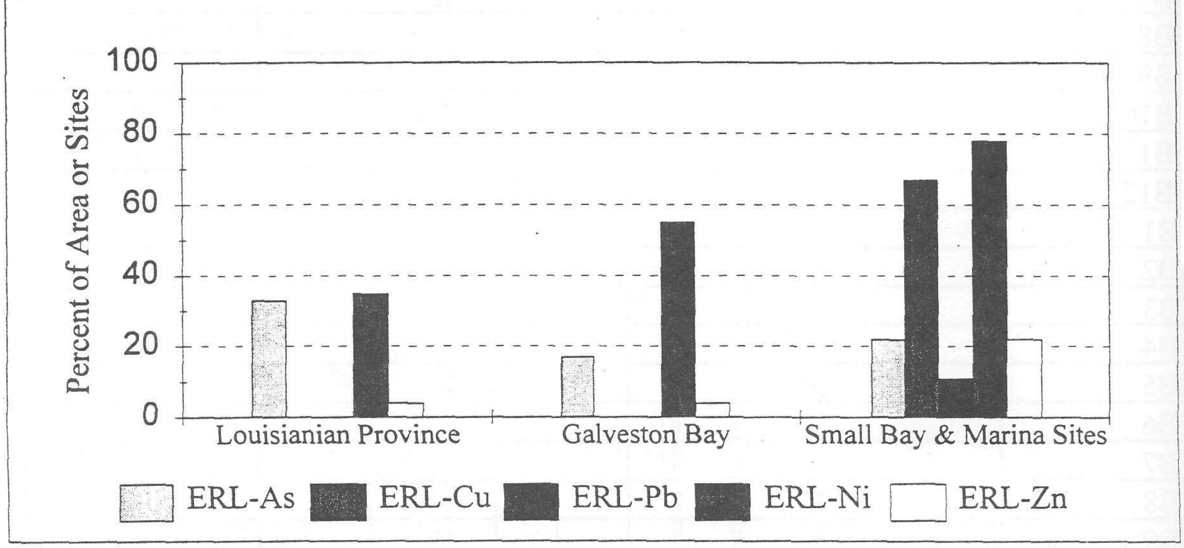


Figure 1. ERL Exceedence for Five Metals.

	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Enrichme	2	9	14	9	15	25	21	26
NOEL exc	8	0	29	7	1	23	15	23
ERL exce	7	0	0	4	0	23	1	3

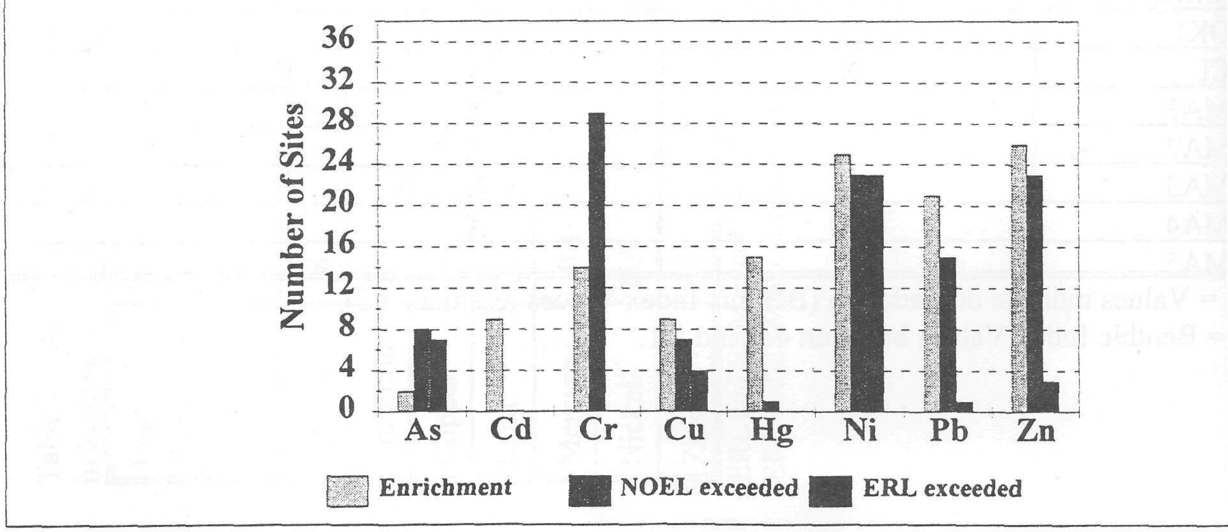
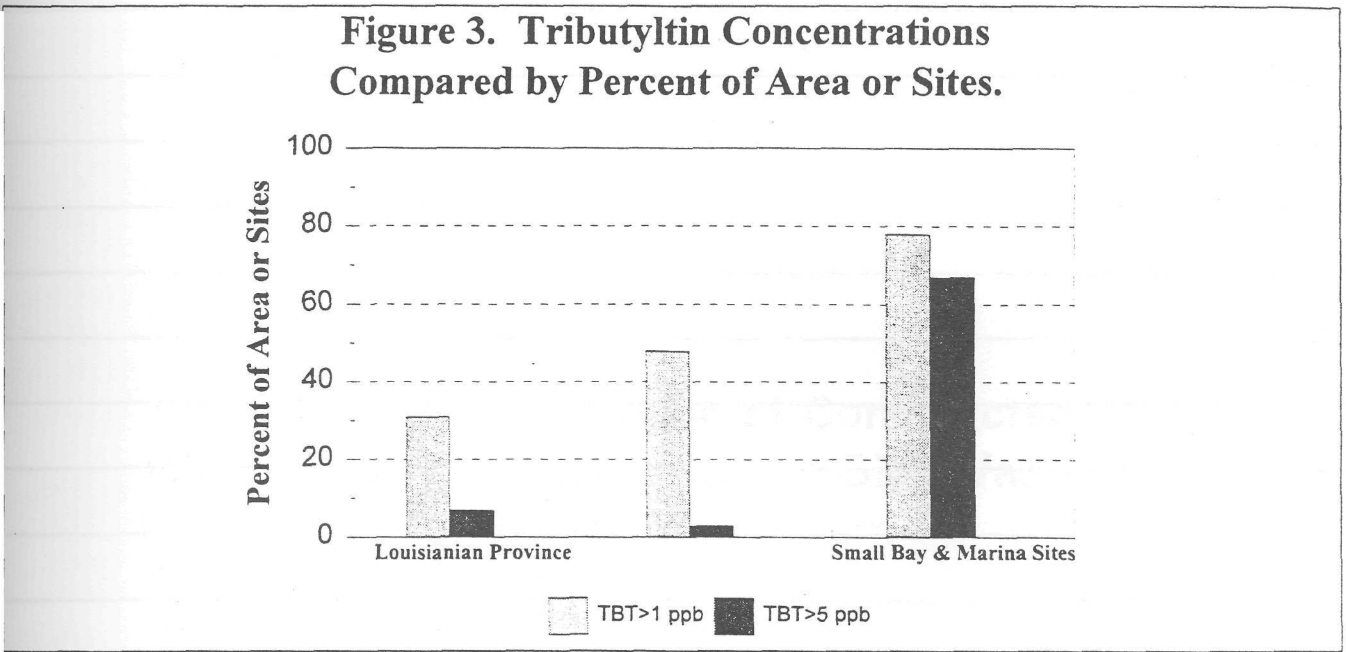


Figure 2. Enrichment and Exceedence of Metals in the Galveston Bay Complex

	TBT>1 pp	TBT>5 ppb
Louisiania	31	7
Galveston	48	3
Small Bay	78	67



	Degraded	Marginal	Undegraded
Galveston	21	27	52
Small Bay	78	0	22